Recent results of ECRH/ECCD experiments on TCV

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The Tokamak à Configuration Variable (TCV) is a Tokamak ($B_T < 1.5$T, $R/a = 0.88$m/0.25m, $I_p \leq 1$MA) characterized by a powerful and flexible ECRH/ECCD system providing up to 3MW in the second harmonic X-mode (X2) and 1.5MW in the third harmonic X mode (X3). The X2 system uses six independently steerable launchers which can be used to vary the injection angles of the EC waves into the vessel in real-time during the plasma discharge, either following a predefined reference or steered by a feedback control system. Additionally, the toroidal component of the injection angle can be varied inter-shot. This provides TCV with the ability to perform experiments featuring on- and off-axis ECRH and co- or counter-ECCD and allows a wide range of plasma scenario and control issues to be explored. Recently, variation of the EC injection angle has been used to successfully control the period of the sawtooth instability in feedback. The sawtooth – a periodic sharp drop in core pressure which can sometimes trigger other MHD instabilities – has a period dependent on the local magnetic shear close to the $q = 1$ surface. This is exploited in feedback control experiments in which the EC deposition location is varied by changing the injection angle during the shot in response to the observed sawtooth period. Another application of the real-time feedback capabilities of the X2 injection angle is the control of the temperature profile in TCV. In preliminary experiments, the soft X-ray emission profile peak has successfully been controlled by varying the injection angle.

The recent TCV experimental programme has given considerable attention to steady-state scenario development featuring internal electron transport barriers (eITBs) and high bootstrap current fractions. Specifically, steady-state discharges with 100% bootstrap current fraction have been achieved by appropriate tailoring of the current and pressure profiles using ECH during fully non-inductive driven plasmas. In fully non-inductive discharges with strong co-ECCD featuring eITBs an interplay between MHD modes and transport barrier formation can lead to global plasma oscillations. TCV experiments have shown how these oscillations can be controlled by modifying the ECH/ECCD deposition or by applying Ohmic current perturbations.

Finally, during experiments on current profile modulation using alternating co/current ECCD, tearing modes have occasionally been triggered. Simulations have confirmed that the local current perturbation close to a resonant q surface is sufficient to affect the stability of tearing modes, leading to stabilization or destabiliziation depending on the direction and location of the injected current. The dependence of classical tearing mode stability on localized current drive will be a topic of study in the coming experimental campaign.